Space Technology Research Grants

Development and Testing of Autonomous On-Orbit Assembly and Servicing Systems Using the SPHERES Testbed

Completed Technology Project (2016 - 2020)

Project Introduction

With the increasing ambition to usher in a new era of exploration beyond our planet and solar system, the scope and complexity of challenges that space technologists face has greatly increased. As the Technology Roadmaps illustrate, there are several fields of science and engineering that need to be further developed before humanity's reach in space can be expanded. As an aspiring space technologist, I seek to address NASA's fourth roadmap: robotics and autonomous systems through the development of autonomous on-orbit assembly and servicing technology. This is still not possible today, yet it is absolutely necessary for future missions to Mars and beyond. With autonomous assembly systems, spacecraft size could increase as they would no longer be constrained by launch vehicle size or the risk of utilizing a manned crew. Furthermore, with the enabling of autonomous servicing technology, the lifetime of important spacecraft could be extended through the repairing or swapping of outdated/broken components. However, the long term vision of the utilization of this technology is in the assembly of space stations and other structures orbiting planets far from earth prior to astronaut arrival. The Synchronized Position Hold, Engage, and Reorient Experimental Satellite (SPHERES) testbed developed by the MIT Space Systems Laboratory (SSL) is currently the only scalable system that provides both testing of control and autonomy algorithms on earth and in 6DOF microgravity via the ISS. As a member of the MIT SSL, the goal of the proposed research will be to develop autonomous assembly and servicing algorithms through incremental iterative testing using the SPHERES platform. The SPHERES Universal Docking Port (UDP) and Halo expansion port (which allows up to 6 docking port attachments) will be used jointly with SPHERES to test the autonomous assembly/servicing algorithms. In order to address an integral part of autonomous assembly technology, algorithm development will begin with developing robust autonomous docking algorithms between a SPHERES satellite and a SPHERES/Halo unit (addressing 4.6 of TA04). This can then be expanded to multiple SPHERES docking to the same Halo unit, multiple SPHERES docking to a spinning Halo unit (and stabilizing it), vision based UDP availability identification (via cameras located on the UDPs), and a SPHERES satellite having to avoid obstacles before docking to a Halo unit. Furthermore, critical to understanding how to control an autonomously docked system will be to continue SSL lead research into understanding how to adapt onboard control/autonomy algorithms and actuation to the new inertial properties of the aggregate system. With robust autonomous docking algorithms developed, tests could then be devised to simulate autonomous assembly/servicing scenarios. For example, if two SPHERES/Halo units are docked together by a single port, an external SPHERE could dock to one SPHERES/Halo unit, detach it from the other, maneuver it to a new location, and reattach it at another Halo Port. Assembly schemes such as this can be developed and tested with increasing complexity and difficulty, addressing critical steps for the maturation of autonomous assembly and servicing technology. SPHERES provides a unique testbed in which algorithms designed for autonomous space

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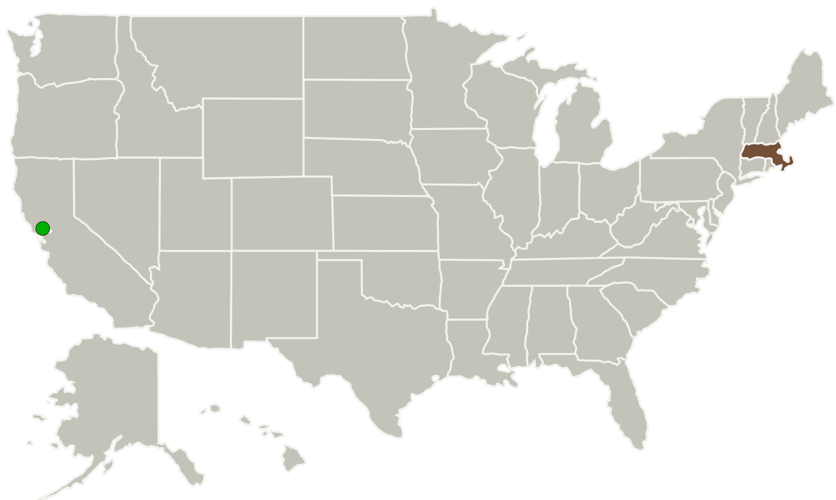
Table of Contents

systems can be tested for long durations in microgravity. With the success of SPHERES formation flight aboard the ISS, autonomous assembly and servicing provides a logical next step in the maturation of the use of their technology. The success of this project would be of great value to NASA as completely autonomous robotic systems with smooth and reliable algorithms in this arena would provide a host of new possibilities for space missions.

Anticipated Benefits

The success of this project would enable the development of autonomous on-orbit assembly and servicing technology that could increase spacecraft size, extend the lifetime of spacecraft, and eventually assemble space stations and other structures orbiting planets far from earth prior to astronaut arrival and would provide a host of new possibilities for future space missions to Mars and beyond.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Massachusetts Institute of Technology(MIT)	Lead Organization	Academia	Cambridge, Massachusetts
Ames Research Center(ARC)	Supporting Organization	NASA Center	Moffett Field, California

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Massachusetts Institute of Technology (MIT)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Alvar Saenz-otero

Co-Investigator:

William D Sanchez

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Primary U.S. Work Locations

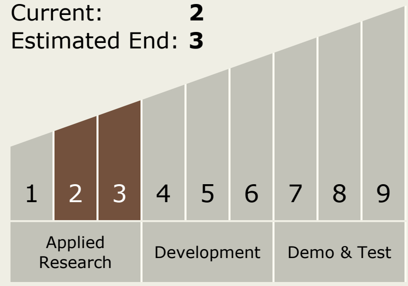
Massachusetts

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX07 Exploration Destination Systems
  - └ TX07.2 Mission Infrastructure, Sustainability, and Supportability
    - └ TX07.2.4 Micro-Gravity Construction and Assembly

Target Destinations

The Moon, Mars, Earth